Bekaert Advanced Coating Technologies
(formerly Advanced Refractory Technologies, Inc., Advanced Coating Division)

# Advanced DLN Films for a Wide Range of Industrial Needs

*In the early 1990s, diamond-like nanocomposite (DLN) films, a new group of thin-film coating materials with unique and versatile properties, were developed by Russian scientists in collaboration with Advanced Refractory Technologies, Inc. (ART), a supplier of advanced materials and technologies, and universities and laboratories in the United States. In 1992, ART acquired exclusive rights to the DLN films and began to aggressively pursue their technical and commercial development.*

*By 1995, many potential applications for DLN films had been identified, and ART sought financial assistance to further explore these possibilities. After obtaining limited funding through private investors, ART applied to the Advanced Technology Program (ATP) and was awarded cost-shared funding in 1995. This project was a high-risk endeavor because the entire field of diamond-like film coatings was new at the time, and DLN technology was in an early stage of development. However, the domestic market potential for DLN coatings was estimated to exceed $100 million annually. By the end of the ATP-funded project in 1997, ART had developed DLN technology and then successfully marketed it in 2000. That same year, the division of the company that produced diamond-like coatings was purchased by Bekaert Corporation (which later became Bekaert Advanced Coating Technologies). As of 2003, the company sells a number of products that utilize DLN technology.*

**COMPOSITE PERFORMANCE SCORE**
(based on a four star rating)
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**Research and data for Status Report 95-01-0131 were collected during January - March 2003.**

## DLN Films Have Superior Characteristics

In the late 1980s, a new group of thin-film coating materials was discovered in Russia. By the early 1990s, these diamond-like nanocomposite (DLN) films were being developed by Russian scientists in collaboration with Advanced Refractory Technologies, Inc. (ART), a supplier of advanced materials and technologies, and universities and laboratories in the United States. DLN films are the most adaptable of thin films. They can be combined with a wide range of metals and ceramics. They also adhere to many substrates, are very hard, resist corrosion, remain stable at high temperatures, and can be produced with a broad range of electrical conductivities.

At the time, there were many thin films that were similar to DLN, including diamond and diamond-like carbon (DLC). Although these competitors had many useful characteristics, they also had drawbacks. Diamond films were crystalline and very hard, and they conducted heat well. However, they did not adhere to many substrates, they did not easily accept other elements into the film coating, and they were expensive. DLC had characteristics ranging from amorphous (formless) to highly crystalline. It was used in applications such as Ray-Ban sunglasses. However, these films were also inflexible and exhibited relatively poor adhesive and electro-optical properties.

## DLN Films Suitable for a Wide Range of Applications

Because DLN films had many superior characteristics, ART wanted to expand the industry's understanding of them and wanted to establish improved manufacturing techniques for the films. Moreover, the company sought to develop targeted applications in four specific performance areas:

- Reduced friction in moving parts, such as bearings and seals
- Increased corrosion and environmental protection of photovoltaic solar panels and sensors
- Improved stability and performance of field-emission devices for flat panel displays
- Improved dielectric materials for X-ray lithography

The company's overall goal was to establish DLN technology as an economically viable process that could yield coatings with a high benefit-to-cost ratio in a wide range of applications. ART needed to meet this goal within a reasonable period of time to effectively compete with overseas manufacturers. The company's ability to minimize the number of iterations required for specific property combinations in DLN films and to demonstrate the manufacturability of new formulations would enable it to reduce the length of time to commercialize the technology.

***DLN films were being developed by Russian scientists in collaboration with Advanced Refractory Technologies, Inc.***

ART realized that the development of DLN technology was a high-risk endeavor. Diamond-like film coatings were new, and DLN technology was in an early stage of development. By 1995, the company had been able to obtain only limited funding for the development effort through private investors. Additional funding would enable ART to accelerate the technology development cycle, shorten the product optimization cycle, and increase the manufacturability and affordability of DLN film coatings. ART turned to government contract opportunities, but these programs were unable to provide the amount of funding the company needed. Therefore, in 1995, ART applied to ATP and was awarded $2 million in cost-shared funding.

### DLN Technology Promises Broad-Based Benefits

ART believed that once DLN technology was developed, its market value would exceed $100 million annually. The use of DLN to improve the tribological (i.e., reduced friction and wear) performance of materials was also expected to have significant market and economic implications.

### ART Develops New DLN Technology

ART sought to develop, within a reasonable amount of time, an economically viable technology to produce coatings that would provide significant advantages in many applications. The company planned to accomplish this by gaining a better understanding of DLN films and their relationship to manufacturing processes and product properties, developing theoretical and empirical models, and improving the deposition process.

An example of a DLN coating on a mold for CDs.

By the end of the ATP-funded project, ART had successfully developed the DLN technology. The company had established specifications and film compositions for a variety of applications. It had also extensively characterized the film properties and performance in a large database, and it then used the data to devise optimal DLN coatings for specific applications.

ART also attempted to demonstrate that it could manufacture DLN coatings by achieving targeted deposition rates, yields, and utilization. The company succeeded in demonstrating specific deposition rates of DLN on silicon.

### Post-Project Commercialization Is Significant Success

At the end of the ATP-funded project in 1997, ART attempted to commercialize the DLN technology through two applications: blades used in electrosurgery (i.e., surgery conducted with electricity) and flat panel displays. For electrosurgical blades, the DLN coating was expected to provide several advantages over the two types of blades currently in use: blades that had no coating, which had a limited life, and blades coated with Teflon, which had a tendency to delaminate and leave residue after surgery. Conversely, DLN-coated blades provide a smooth cut, are reusable, have a long life, and require much less power for cutting. ART anticipated that the use of DLN-coated blades would be widespread because, at the time, more than 80 percent of invasive surgeries in the United States used electrosurgery. ART also believed that DLN-coated blades would help to improve the standard of care available in the healthcare industry.

In January 1998, after the conclusion of the ATP-funded project, ART established a business venture for electrosurgical blades and aggressively pursued manufacturing and scale-up plans. However, in 1999, after experiencing coating adhesion problems, the company decided against pursuing this venture.

### *ART attempted to commercialize the DLN technology through two applications.*

For the flat panel displays application, DLN coatings can be used on spacers in field emission devices to improve picture clarity and appearance. ART aggressively pursued product development and hoped to design and construct a prototype that a U.S. customer could use to compete with overseas manufacturers in this multibillion dollar industry. However, the customer, which had been developing its own technology, ultimately decided not to pursue the DLN technology.

ART began to successfully commercialize DLN technology in 2000 by promoting its use in semiconductor applications. That same year, the division of the company that produced diamond-like coatings was purchased by Bekaert Corporation, a global group headquartered in Belgium, that had experience using DLN technology. In 1996, Bekaert had licensed the technology from ART for plastic molding applications in Europe, where the technology had been used for several years. The new division became Bekaert Advanced Coating Technologies division.

From 2000 to 2002, the new division's revenue grew from approximately $60,000 to well over $1 million. To accommodate the increased demand for DLN-coated products, Bekaert began constructing a coating facility in Amherst, NY, that was four times the size of the facility used by ART. Bekaert also hired production personnel to meet the increased demand.

### *DLN technology could yield a high benefit-to-cost ratio in a wide range of applications*

In 2003, the division is selling a number of products with DLN coatings:

- Molds for CDs and DVDs in which the coating reduces abrasion and wear in the transfer of data, decreasing the need for machine maintenance
- Coatings on blow-molding components used in manufacturing plastic juice bottles where the coating is used inside the mold to reduce sticking and to retard plastic residue buildup, resulting in increased productivity and reduced maintenance
- Coatings for components used in semiconductor cluster tools

The division is also using DLN technology to coat tools used in metal-forming applications, such as soda and beverage cans. The DLN coating extends the life of the tool, resulting in increased productivity. According to Bekaert management, "The division has had an extraordinary growth rate. From 2001 to 2002, it was 120%. This year [2003], it has been slightly lower, but better than 50% growth is expected."

Since the ATP-funded project began in 1995, ART has filed for and been granted four patents for the DLN technology. The company has also made presentations and has published a paper about DLN's tribological, electrical, thermal-stability, and corrosion-resistance properties.

## Conclusion

By the end of the ATP-funded project, Advanced Refractory Technologies, Inc. (ART) had successfully reached its goal of developing diamond-like nanocomposite (DLN) technology. ART had established specifications and film compositions for a variety of DLN applications. In 2000, ART sold the division that produces diamond-like coatings to Bekaert Corporation. In that same year, the new division of Bekaert (Bekaert Advanced Coating Technologies) began to successfully market DLN coatings. Today, in 2003, the division is selling a number of products, including coatings on molds for CDs and DVDs, coatings on blow-mold components used in manufacturing juice bottles, coatings on semiconductor process components, and coatings on metal-forming tools.

# PROJECT HIGHLIGHTS
## Bekaert Advanced Coating Technologies
## (formerly Advanced Refractory Technologies, Inc., Advanced Coating Division)

**Project Title:** Advanced DLN Films for a Wide Range of Industrial Needs (Diamond-Like Nanocomposite Technology)

**Project:** To develop scientific understanding and basic process-control information to enable the use of diamond-like nanocomposite (DLN) films, a new family of thin-film materials, in a wide range of industrial applications.

**Duration:** 8/1/1995-12/31/1997
**ATP Number:** 95-01-0131

**Funding (in thousands):**

| | | |
|---|---|---|
| ATP Final Cost | $1,996 | 54% |
| Participant Final Cost | 1,677 | 46% |
| Total | $3,673 | |

**Accomplishments:** During this project, Advanced Refractory Technologies, Inc. (ART) successfully developed DLN coating technology. The company established improved manufacturing techniques for DLN films and developed several applications, such as electrosurgical blades and flat panel displays.

Since 1995, ART has been granted the following patents:

- "Capacitive thin films using diamond-like nanocomposite materials"
  (No. 5,638,251: filed October 3, 1995, granted June 10, 1997)
- "Electrically tunable low secondary electron emission diamond-like coatings and process for depositing coatings"
  (No. 6,013,980: filed May 9, 1997, granted January 11, 2000)
- "Fluorine-doped diamond-like coatings"
  (No. 6,468,642: filed December 2, 1998, granted October 22, 2002)
- "Electrically tunable low secondary electron emission diamond-like coatings and process for depositing coatings"
  (No. 6,486,597: filed October 21, 1999, granted November 26, 2002)

In addition, the company has published and presented five papers that describe the results of its work.

**Commercialization Status:** Bekaert Advanced Coating Technologies is currently selling a number of products with DLN coatings. These include components that are used in manufacturing CDs, DVDs, polyethylene terephthalate juice bottles, and metal cans and components used in semiconductor cluster tools.

**Outlook:** Since 2000, when Bekaert Advanced Coating Technologies began to successfully market the DLN coatings, the division has grown steadily, with commercial revenues exceeding $1 million in 2002. The revenue growth, which has resulted in additional jobs at Bekaert, is expected to continue at a steady pace in 2003. According to Bekaert management, the coatings are "just now finding a market segment." The division is realizing the benefits of the research and development conducted during the ATP-funded project, and management "is confident that the technology will only mature and there will be more and more products."

In the future, Bekaert is considering other uses of the technology. For example, applications include using it on tools that produce pharmaceutical tablets to eliminate abrasion from the medicinal powder; for automobile engine components to decrease friction and increase the life of the parts; and for biomedical applications, such as surgical tools, to increase the efficiency and life of the tool.

**Composite Performance Score:** * * *

**Number of Employees:** 15 employees at project start in the division (ART), 18 at Bekaert as of January 2003.

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